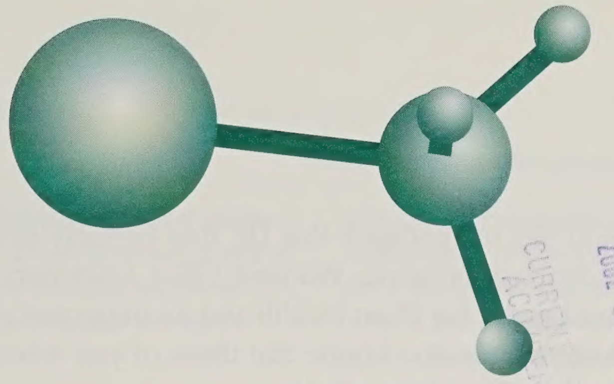
Methyl Bromide *Alternatives*



USDA

Vol. 7, No. 1
January 2001

Inside This Issue

This issue and all back issues of the *Methyl Bromide Alternatives* newsletter are now available on the Internet at **<http://www.ars.usda.gov/is/np/mba/mebrhp.htm>**.
Visit the ARS methyl bromide research homepage at **<http:/www.ars.usda.gov/ismbmebrweb.htm>**.

This newsletter provides information on research for methyl bromide alternatives from USDA, universities, and industry.

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From the Agricultural Research Service Administrator

The loss of methyl bromide for most current uses is now only 4 years away. With the latest Montreal Protocol-mandated reduction that occurred January 1, 2001, the availability of methyl bromide is reduced to 50 percent of what it was in 1998. Availability will be further reduced to 30 percent of the 1998 baseline in 2003. Methyl bromide shortages and increased costs for the available methyl bromide will present daunting challenges to many growers and other users as they try to adapt to this changing environment. Although research isn't the sole answer to finding methyl bromide replacements, it is a vital part of that activity. ARS intends to continue working as hard as we can with growers and other methyl bromide users, public and private scientists, and regulatory officials to make the widest array of methyl bromide alternatives available for the greatest number of uses possible.

Even though much work remains to be done, progress has been made. For some major crops, adequate alternatives have been found that will continue profitable operation by growers. In some cases, technically effective alternatives cannot be fully utilized because of regulatory constraints. USDA is working closely with the U.S. Environmental Protection Agency and state regulatory agencies to find safer ways to use these pesticides so that restrictions can be relaxed.

Small-acreage crops continue to be at highest risk of not having methyl bromide alternatives. With limited resources, ARS and other research organizations have been forced to focus their efforts on the crops that use the most methyl bromide. To add to this problem, pesticide companies have been reluctant to register pesticides for small-acreage, high-value crops. Many floriculture crops fall in this category. In recognition of this situation, Congress appropriated in its FY 2001 budget enough new funds to allow ARS to hire two new scientists to work on methyl bromide alternatives for floriculture crops. One scientist will be located in Florida and the other in California; recruitment for both is under way.

Finally, I would like to announce that Dr. Roy Gingery has returned to active research and has accepted a research leader position at our Wooster, Ohio, laboratory. For the last 7 years, he has been ARS National Program Leader for Plant Health and an important part of our ARS methyl bromide alternatives research management team. I hope that those of you who have worked with him over the years will join me in thanking him for a job well done.

Best wishes,

Floyd Horn
Administrator

Methyl Bromide Alternatives: Winding Their Way Through EPA

Since the announcement that methyl bromide would be phased out due to its role as an ozone-depleter, the focus has been on finding new alternatives and getting them to market for use by industry. Throughout that time, the Environmental Protection Agency (EPA), the lead Federal regulatory entity, has been responsive to the needs of commercial growers by working with methyl bromide researchers, who are identifying viable alternatives, and the companies that are developing the data to support registration of these alternatives.

The need of the Nation's growers to have an effective replacement, or combination of replacements, for methyl bromide, remains the focus of the USDA-EPA Methyl Bromide Alternatives Working Group. USDA's Cooperative State Research, Education, and Extension Service (CSREES) and ARS sponsored research programs with IR-4s methyl bromide alternatives research efforts to identify efficacious alternatives. EPA's role is to identify data that needs to be generated and review it to make registration decisions in a timely manner.

The Review Process

To that end, EPA decided an expedited review of methyl bromide alternatives was warranted. The normal time required to review an application for a new ingredient chemical, from receipt to decision, is approximately 31 to 36 months. An expedited review process is completed in about 18 to 22 months.

The long time frame, however, intrudes on the patent-protection period. Since many companies apply for patents before the formal application review process, it is imperative to proceed as quickly as possible. Generally, patents are in force for 7 years, and the amount of time taken for review and approval reduces that patent-protection time. Also, since the product is not on the market during part of the patent-protected period, there is unrecoverable lost revenue during that time.

The path to approval can prove long and laborious. EPA establishes review priorities and schedules for new active ingredients and other submissions for each fiscal year. Because of the extraordinary circumstances surrounding the methyl bromide phaseout, applications for alternatives are expedited—given top priority for review in the scheduling process and are reviewed before other scheduled submissions.

Under the current process, new chemical registrations first undergo front-end processing, for about a month, which includes screening by staff for adherence to format and by scientists for scientific viability. Next, in-depth science reviews, lasting 14 to 22 months, are conducted for health effects, residues on crops, lab validation of analytical methods for detecting residues, worker and residential exposure, ecological and environmental effects, and potential drinking water exposures. Following this, peer review and risk assessments are executed, during which safety factors, hazards, and risks are examined; this takes about 5-1/2 to 8 months to complete. The process then continues with risk management and a regula-

tory decision—risk assessors review risk-mitigation measures and work out solutions with the registrants. This step takes from 1 to 3 months. If approved, the *Federal Register* notice is prepared, programwide concurrence is obtained, management signatures are affixed, and the notice is published for public review.

As cumbersome as this may seem, it is speedy by normal standards, but those in industry would like to see an even swifter pace. Bruce Houtman is the global regulatory leader for Dow AgroSciences' methyl bromide alternatives products, including Telone (1,3-dichloropropene) and Vikane/Profume (sulfuryl fluoride). Houtman says, "It is important to understand what an expedited review is and what it isn't. An expedited review shortens the period that the registration package waits for review, but it doesn't shorten any aspect of the review itself. An expedited review is as thorough, complete, and comprehensive as all other EPA reviews. In the case of all regulatory reviews, the process could be made more efficient and provide new agricultural tools to the grower community more quickly by applying additional resources."

EPA Steps To Improve Process

EPA has made considerable efforts to become service-oriented. "EPA has approached perceived inadequacies by knowing and working with our customers—the registrants," says Peter Caulkins, associate director of EPA's Registration Division. Preregistration conferences have proven quite useful to EPA and registrants.

"The chance to sit down face-to-face with agency representatives resulted in better results and an overall positive experience," according to Dr. Randy Deskin, director of regulatory affairs and toxicology for Cytec Industries, Inc. Cytec Industries, based in New Jersey, is a specialty chemical manufacturer with about $1 billion a year in sales and a successfully registered phosphine gas fumigant called Eco2Fume.

Caulkins also believes information provided to registrants can be empowering. For instance, the average rejection rate for data submitted by registrants was 33 percent in 1988. "EPA provided each registrant with their company-specific rejection rate, as well as the rejection rates of their competitors, which provided a tremendous incentive for them to improve," he explains.

"A huge amount of time and resources were being wasted in rework," says Caulkins. "Studies often had to be returned to be upgraded and resubmitted, or studies needed to be repeated." EPA identified the rejection factors that most frequently occurred for each study required, and they, along with company scientists, worked together to find solutions.

This was the first time many of the company scientists were involved with EPA to address specific rejection factors. The cooperation allowed EPA and commercial scientists to identify and solve prevalent rejection factors. The sharing of this information also allowed companies to benefit from each others' experiences in a noncompetitive fashion. By 1998, the industry-wide average rejection rate had been reduced from 33 percent to 3.6 percent. Through a combination of such information and services, registrants have shown an enhanced ability to be successful with their data submissions the first time around.

What's Next?

EPA will continue working with registrants to approve those chemicals which are acceptable to their standards. But the pace of approvals is still slow, according to many chemical companies. "While the agency has been very responsive and communicative, industry feels the process could still be faster," says Deskin.

Houtman says, "The industry recognizes that the limiting factor is EPA resources." To that end, a fee-for-service program, like one in place at the Food and Drug Administration, is being discussed by industry executives. Fee-for-service would involve registrants paying EPA to hire additional staff and contractors to review the applications. However, industry representatives would have to appeal to their congressional representatives to get such a system and the necessary funds, with accountability, in place.

Even with the long registration process, registrants are encouraged. "This is a good deal for the agricultural community because registering methyl bromide alternatives is a high priority for EPA, as well as for registrants," says Houtman.

Methyl Bromide Phaseout and Florida Floriculture

Florida is the second largest floriculture producer in the country, with over $650 million in sales in 1998. More than 1,500 growers commit 14,500 acres to floriculture, including cut flowers, potted flowering plants, and bedding/garden plants.

While floriculture is a vital part of Florida's agricultural economy, it pales in comparison to other crops in the amount of methyl bromide used. The U.S. utilizes about 38 percent of all methyl bromide applied worldwide each year. About 79 percent of the methyl bromide produced in the U.S. is used for soil fumigation before planting crops, about 9 percent is used to fumigate harvested commodities

during storage and export, and about 5 percent is used for structural fumigations, such as for food processing plants, warehouses, museums, antiques, and transport vehicles. The remaining 7 percent is used in the production of other chemicals.

Florida accounts for about 38 percent of preplant methyl bromide use in the U.S. Fresh-market tomatoes and peppers grown in Florida account for about 33 percent of the Nation's preplant methyl bromide use and about 88 percent of the State's preplant methyl bromide use. Strawberries account for an additional 8 percent of preplant use there. Together, strawberries, tomatoes, and peppers constitute 96 percent of preplant methyl bromide used in Florida, providing a strong impetus to find methyl bromide alternatives for these crops.

The remaining crops, including floriculture crops, use about 4 percent of preplant methyl bromide. Unfortunately, because this sector of agriculture uses such a small amount of methyl bromide, the stimulus to fund research has been very low. However, some potential alternatives for caladiums and chrysanthemums have been identified.

Caladiums

More than 95 percent of the world's production of caladium tubers comes from a small geographical region close to Lake Placid, Florida. Most of the production is on muck or high-organic-matter soils. Soilborne pest control is a major problem for producers. These pests include weeds, root-knot nematodes, and soilborne diseases, such as *Fusarium*.

James Gilreath, Robert McSorley, and Robert McGovern, at the University of Florida, Gulf Coast Research and Education Center, in Bradenton, studied soil fumigant and herbicide combinations for soilborne pest control in caladium in 1998. Treatments consisted of methyl bromide + chloropicrin (90 percent/10 percent), 1,3-dichloropropene + chloropicrin (83 percent/17 percent), and metham + chloropicrin (75 gal/acre + 200 lb/acre. A nontreated control was included in the study. Plots treated with 1,3-dichloropropene or metham were given soil-surface sprays of metalochlor during planting and oryzalin about 7 weeks later. Plots treated with methyl bromide received only oryzalin; nontreated controls received no herbicide and were hand weeded.

Early (25 days after application in midsummer) weed control was good with treatments that included metolachor, but methyl bromide plots displayed early infestations of crabgrass and pigweed, indicating that they, too, may have benefitted from metolachlor at planting. This may also suggest methyl bromide evacuated from the top 2 inches of soil too quickly for good weed control. Oryzalin was still providing good weed control 75 days after application, and the chemical reduced the total number of all weed plants, compared to areas where no herbicide was applied. Oryzalin was still providing good control of pigweed, purslane, and *Linnaria canadensis* (a winter annual), a late emerging weed, 119 days after application and 54 days after the final weeding.

The methyl bromide + chloropicrin plot exhibited early infestations of crabgrass and pigweed, but control of soilborne pests, such as *Fusarium,* was equivalent to all other treatments. Tuber production was equivalent to the metham + chloropicrin plot. Nematodes were not present in any soil samples of any plots.

Metham + chloropicrin, with a surface application of metolachlor and oryzalin, displayed excellent early control of weeds, but control of soilborne disease pests, such as *Fusarium,* was not statistically different from the untreated control.

1,3-D + chloropicrin, along with a surface application of metolachlor and oryzalin, displayed excellent early control of weeds. This method also performed equivalently to all other treatments in disease pest control. In this treatment, more jumbo tubers were produced than in other treatment plots.

Research results suggest that 1,3-D + chloropicrin (83 percent/17 percent) at 35 gal/acre may be a viable replacement for methyl bromide, when combined with metolachlor herbicide at planting, followed by a midsummer application of oryzalin. This research is being continued to determine the long-term effects of these fumigant and herbicide combinations on pest control and tuber production.

Steam Sterilization in Chrysanthemums

The lack of research in floriculture has forced some growers to find their own solutions. Yoder Brothers in Alva, Florida, looked at steam sterilization to control soilborne pests, as compared to methyl bromide. "Methyl bromide is the backbone of our IPM strategy," says Patrick Crump, director of production for Yoder Brothers. "It is used after every crop rotation to prepare the soil for planting, and it is used to meet quarantine restrictions."

Yoder Brothers installed two stationary boilers (250 horsepower) with overhead pipes leading to the beds at a cost of $500,000 to treat one-third of their 1.3 million square feet of beds. The method seems to work, but is very expensive. "If we were to use this method exclusively, costs would increase by $800,000 per year," explains Crump. This amount would fluctuate depending upon labor and

diesel fuel costs. "Methyl bromide is easier from a management standpoint," he says.

There are some problems facing steam sterilization. Because growers are working in an open area, the steam dissipates, which means applying it for longer periods of time. The amount of soil moisture and temperature also affects the amount of steam used and the duration of treatment.

Yoder Brothers met the first 25 percent reduction in methyl bromide availability without too much difficulty. "We achieved a 6 to 7 percent reduction by calibrating our equipment and reducing waste," says Crump.

With steam sterilization, Crump found yield to be the same or slightly better than with methyl bromide. "But the yield doesn't warrant the increased costs associated with steam sterilization," Crump warns.

Now that the 50-percent methyl bromide reduction is in effect, Yoder Brothers will have to add another phase of steam, resulting in $1.5 million in boiler expenses, to cover 1.3 million bed square feet. As of October 1, 2000, Yoder Brothers' cost to steam sterilize the soil was $1,550 per 10,000 square feet, compared to $685 for methyl bromide treatment. "Unless someone comes up with something else, we will have to use steam sterilization," says Crump.

ARS recognizes the dearth of research in floriculture and is addressing the gap. As noted in ARS Administrator Floyd Horn's letter on the cover of this issue, Congress appropriated funds in the FY 2001 budget to hire two new scientists to research methyl bromide alternatives in floriculture crops.

According to James Gilreath, "Telone products will be part of everyone's package solution. Some cut flowers are in good shape for herbicide options, but many are not." ARS' additional funding and resources may provide some relief in the long-term, but choices are limited in the short-term.

Application Technology for Injecting Telone

Current reductions of methyl bromide and the eventual loss of the gas fumigant in 2005 have prompted a lot of research in a relatively short period of time. Researchers have conducted numerous studies to find a chemical or chemical combination to replace methyl bromide. In the meantime, some researchers are exploring new ways to use existing chemical fumigants.

Telone is an effective fumigant against nematodes and soilborne disease and, when combined with an herbicide, it can approximate the control of methyl bromide. However, regulations that govern personal protection equipment and buffer zones make its use prohibitive for some.

John Mirusso, fumigation consultant to Dow AgroSciences, developed a piece of farm equipment that injects Telone into the soil and slows its escape. Mirusso contacted Yetter Farm Equipment of Illinois 2 years ago to discuss modifications to a coulter assembly to accommodate soil injections of Telone. "John told us he needed a piece of equipment that could handle field residues from previous crops and inject a fumigant to a depth of 12 inches, with minimal soil disturbance," recounts Mark Seipel, regional sales manager for Yetter.

Yetter, a 71-year-old business, focuses mostly on equipment for use in the Corn Belt. Seipel says, "Our equipment, historically, is used for conservation tillage and fertilizer placement, but grower needs are changing. Telone injection is a new avenue we are pursuing due to the methyl bromide phaseout. The market is changing so changes in technology and application are needed."

The new 2986 coulter 30-inch Avenger, took several months of development by Mirusso, the Yetter company, and Jerry Nance, Dow AgroSciences' Telone specialist. "It features, as indicated in its name, a 30-inch coulter that allows for fumigant application up to 12 inches, as compared to 6 inches with a standard Yetter coulter," says weed scientist James Gilreath of the University of Florida's Gulf Coast Research and Education Center, Bradenton.

"We looked at a lot of equipment before settling on the 2986 coulter 30-inch Avenger," says Nance. "The emissions are very low, so using the rig makes fumigating the field a one-person job. This significantly affects growers, who must use personal protection equipment when fumigating."

Sealing devices were added to the knives that follow the coulter. The knife has a tube in the back side that delivers the fumigant to the bottom of the groove. The beaver tail is angled so it compacts or presses a bit of soil about 3 inches from the bottom of the chisel groove. "This keeps the fumigant from moving rapidly up the groove and dissipating into the atmosphere," explains Gilreath.

Following each coulter assembly is a set of press wheels that presses the soil surface to seal the knife and coulter groove at the surface. The amount of force applied to them is adjustable. "One can use chisels without the coulter," Gilreath says. But he

cautions, "If there is tying string or plastic mulch residue in the soil, it gets hung up on the chisels and can be dragged around. This results in chisel grooves substantially larger than the chisel itself, and this allows rapid outgassing of fumigant."

According to Nance, this is definitely not what a grower wants. "You want the chemical in the ground to do its job and then degrade. What escapes is unused and useless product."

It also contributes to air emissions that can affect the size of buffer zones. "Air emissions are measured to help determine buffer zones. If the fumigant does not escape into the air, then neighbors are not exposed to the fumigant," says Peter Caulkins, associate director of EPA's Registration Division.

So far, the amount of outgassing is low, according to Mirusso. "The numbers look great and the Telone is expanding out at the depth of injection, which increases effectiveness."

These types of innovative collaborations will have to continue to adjust to life without methyl bromide. "Agriculture is going through tremendous changes now and modifications are necessary. The best products are made with input from our consumers—the farmers," says Seipel.

Technical Report

Approaches For Management of Root Diseases of Strawberry

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Essentially all of the approximately 25,000 acres planted to strawberry in the state of California are fumigated with methyl bromide + chloropicrin to control root diseases and weeds.

Historically one of the primary reasons for soil fumigation was to reduce the incidence of Verticillium wilt, the most important lethal disease of strawberry. However, a number of other nonlethal soilborne fungal pathogens also can contribute to significant losses when strawberry is grown in nonfumigated fields. In one field plot that did not have Verticillium wilt a 46 percent reduction in marketable yield was observed in 1998 when the strawberry cultivar Selva was grown in nonfumigated soil; based on root isolations this yield decline was attributed to root rot caused by *Pythium,* binucleate *Rhizoctonia*, and *Cylindrocarpon* spp. Collectively these general, nonspecific pathogens cause a root disease commonly referred to as black root rot, a name that is descriptive of the appearance of the roots (reviewed in Wing et al., Advances in Strawberry Research 13:13-19). Depending on the production location, the lesion nematode *Pratylenchus penetrans* has also been associated with this disease complex (LaMonda, J. A. and Martin, S. B. 1989. Plant Dis. 73:107-110). Sample assays of test plots in Watsonville and Salinas did not reveal significant nematode levels in our research plots, so the research effort has focused on the fungal pathogens. Greenhouse trials have confirmed the involvement of the isolated fungal pathogens in the disease complex and their ability to stunt plant growth (described in more detail below; Martin, F.N. 2000. Phytopathology 90:345-353). In fact, in view of the high level of recovery of these pathogens from the roots the first 4-5 months after transplanting it is suspected that they contribute to the significant reductions in plant growth observed when strawberry is grown in nonfumigated soil. At both the Watsonville and Salinas test plot locations reductions in shoot growth by 10-15 percent are often observed within 8 weeks of transplanting for plants grown in nonfumigated soil; the root systems of these plants also are less well developed and have necrotic lesions. This translates into a smaller, less thrifty plant in the early spring that is not able to support the fruiting level that is expected for plants in an economically viable production field. Attempts to control these pathogens are being approached from several directions:

Host Tolerance

One approach for mitigating the loss of methyl bromide soil fumigation for disease control would be to plant strawberry cultivars that are tolerant to specific root pathogens. Screening programs are currently underway in other laboratories in California evaluating tolerance to Verticillium wilt and Phytophthora root and crown rot. These are two important diseases of strawberry that can cause significant crop losses by reducing yield as well as killing the plant. The efforts of this research program have focused on determining the contribution of the individual pathogens associated with black root rot on the severity of the disease complex in the field as well as evaluating host germplasm for pathogen tolerance in the greenhouse and field. The most common *Pythium* spp. encountered in the central coastal California production area is *Pythium ultimum*, a broad host range species. The *Rhizoctonia* spp. most commonly encountered are binucleate species in anastomosis group (AG) A, G, and I.

Greenhouse Trials

Greenhouse evaluations for tolerance to *Pythium ultimum* and different AGs of binucleate *Rhizoctonia* (a mixture of isolates in AG-A, –G, and -I) revealed different levels of tolerance to these pathogens among the various cultivars. In evaluations with *P. ultimum* at 200 p/g soil, Aromas, Selva, Seascape and Carlsbad exhibited greater tolerance to the pathogen

than did Camarosa, Chandler, Torrey and Pajaro, which were susceptible. The presence of the binucleate *Rhizoctonia* isolates caused significant reductions in shoot growth for all cultivars examined, with the cultivars Capitola, Diamante, Laguna, Selva, and Seascape exhibiting the greatest level of tolerance.

Field Evaluations

Field trials to evaluate cultivar performance in nonfumigated soil have been conducted in test plots in Salinas. The location has not been previously fumigated and is naturally infested with the pathogens associated with black root rot. Importantly, Verticillium wilt and Phytophthora root and crown rot have not been a problem at this test location, so trials evaluating the contribution of the general root pathogens associated with black root rot on plant growth and yield can be conducted independent of these lethal pathogens. In an effort to build up black root rot pathogens in the plots, strawberry was cropped in the test plots for 2 years prior to initiating these trials.

There were dramatic differences in growth and yield performance among the cultivars. Analysis of variance reveals that these differences are significant ($P < 0.001$ between fumigation treatments; $P < 0.001$ between cultivars; $P = 0.0032$ for fumigation x cultivar interaction). With the exception of Laguna, all cultivars exhibited significant reductions in plant diameter measurements for 5 1/2–month-old plants when grown in nonfumigated soil compared to the MB + Pic fumigated control. The greatest reduction in growth was observed for Oso Grande, which had approximately a 50 percent reduction in plant diameter. Camarosa and Diamante exhibited growth reductions of 30 percent while the remaining cultivars evaluated had reductions ranging from 10-20 percent.

A wide range in yield also was observed among cultivars. For example, there was no difference in total yield for Capitola grown in nonfumigated compared to the fumigated control; in contrast Oso Grande, Camarosa, and Diamante exhibited approximately a 70 percent, 45 percent and 52 percent reduction in yield, respectively, when grown in nonfumigated compared to fumigated soil. While the yield in nonfumigated soil was proportional to the yield in fumigated soil for some cultivars, this was not observed for all comparisons. For example, total yield in fumigated soil for Gaviota, Irvine, Laguna, and Oso Grande were similar (data not shown), however, in nonfumigated soil Oso Grande has dramatically lower yields than the other cultivars.

Based on the greenhouse evaluations it appears that there is a differential sensitivity of cultivars to some of the general root-rotting pathogens. Likewise, field evaluations confirm that there is a range in cultivar performance when grown in nonfumigated soil naturally infested with pathogens responsible for causing black root rot. Unfortunately, some of the more tolerant and best performing cultivars tested are no longer used commercially due to undesirable horticultural traits. However, knowing that there are cultivars more tolerant of these pathogens may assist future efforts at developing new cultivars with reduced susceptibility to disease.

Crop rotation

A number of strawberry root pathogens have a broad host range and are capable of infecting other crops, so in the absence of effective soil fumigation crop rotation can have a significant influence on maintaining populations of soilborne pathogens. Field trials evaluating the influence of rotation with broccoli, Brussels sprouts, or lettuce on the population dynamics of *Pythium* spp. and *Verticillium dahliae* are in progress at the Watsonville test site (done in collaboration with Dr. Krishna Subbarao, UC Davis and Steve Koike, Monterey County Cooperative Extension). The field was cropped in vegetable rotation in the 1997 season, strawberry (Selva) in the 1998 season, vegetable rotation in 1999 and was in strawberry in 2000. After harvesting the vegetable crops, the stubble was mowed with a flail mower, allowed to dry on the soil surface for several days and then incorporated into the soil. Two cropping cycles were planted for broccoli and lettuce and one for Brussels sprouts. While cropping practices had no consistent influence of population densities of total *Pythium* spp., broccoli and Brussels sprouts reduced *V. dahliae* inoculum densities by 80-90 percent (to a final inoculum density of 1-2 microsclerotia/g soil). Although the market yield for all rotation treatments was below the MB + Pic fumigated controls in 1998, strawberry grown in the broccoli rotation plots had only a 23 percent reduction in yield compared to the fumigated control while Brussels sprouts and lettuce had yield reductions of 31 percent and 39 percent, respectively. Strawberry yield data for the 2000 season is currently being analyzed. These trials have been expanded at the Watsonville test site to include larger test areas as well as the addition of a test plot in an organic production field. Similar experiments (rotation with broccoli, cauliflower, or lettuce) also are under way at the Salinas plots as well to evaluate the effect of rotation treatment on black root rot pathogen population dynamics and disease severity.

The influence of root colonizers of root health, plant growth, and yield

Preliminary investigations on the population structure and seasonal fluctuations of fungal, bacterial, and actinomycete root colonizers have been done for plants grown in fumigated and nonfumigated soils. A number of the recovered isolates have been evaluated for their effect on shoot and root growth in greenhouse/growth chamber trials. While most isolates had no effect on plant growth, some were identified that increased either shoot growth (up to a 40 percent increase), root growth (up to a 138 percent increase), or a general stimulatory effect on both shoot and root growth. Several isolates also were identified that had inhibitory effects on root growth (up to a 26 percent reduction). Trials in the 1998 season at the USDA test site in Salinas in nonfumigated soil identified several beneficial isolates that significantly increased yield over the untreated control plants when plants were treated at the time of transplanting (one isolate gave a 35.5 percent increase in marketable yield). However, trials in the 1999 season did not reveal significant differences among the treatments. One possible reason for this could be that there was much less rainfall in 1999 compared to 1998 (31 vs 74 cm, respectively). Since soil moisture can have a significant effect on the ability of introduced microbial inoculants to colonize roots, the drier conditions in 1999 could have lead to lower root colonization levels which in turn would lead to a reduced effect on strawberry yield. To alleviate potential problems with insufficient root colonization, trials are in progress with several of these isolates where additional treatments with the microbial inoculants are applied via the drip system. Trials evaluating the efficacy of several commercial biological control agents are under way as well.

Fumigation trials

Fumigation trials have been done in collaboration with Husein Ajwa (USDA-ARS, Fresno, CA) to evaluate the efficacy of alternative fumigants and methods for application for their ability to control *Pythium ultimum*. Naturally infested soil was placed into nylon mesh bags and buried at two depths 8 cm from the center of the strawberry beds. The bags were recovered 6.5 weeks after fumigation and the pathogen populations determined by plating on a selective medium. All fumigation treatments completely eliminated *P. ultimum* with the exception of the Telone C-35 treatments at the 40 cm depth (20 percent and 10 percent survival for the drip and shank treatment, respectively). One possible reason for this could be spacing of the drip tape or bed fumigation shanks in relation to where the inoculum bag was placed. Assays also were conducted in naturally infested field soil with the fumigants applied through the drip lines; Iodomethane + Chloropicrin (1:1) at 200 lbs/acre and propargyl bromide at 180 lbs of 80 percent AI/acre controlled *P. ultimum* in the planting line of the bed to a depth of 25 cm. Additional trials evaluating fumigation efficacy in strawberry nursery and fruit production fields is currently in progress with collaborators from Industry, the California Strawberry Commission, USDA-ARS, and the University of California.